Proton Widths of Light Nuclei

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WHEN evaluating resonances in nuclear reactions involving charged particles, it is convenient to separate from the observed widths the known energy dependent factors so as to get some absolute measure of the reaction probability which can be compared for different resonances and different nuclei. This separation is frequently expressed by

$$\Gamma = P(E)^{\frac{1}{2}}G,$$

where Γ is the observed width, P is the barrier penetration, E is the energy in Mev, and consequently G is the width at 1 Mev without barrier. For definiteness we take E to be the bombarding energy in proton induced reactions. G is known to vary from over 1 Mev for the 450-kev level in C^{12}+protons (see article by Fowler, Lauritsen, and Lauritsen) to a few ev for neutron reactions in intermediate and heavy nuclei.

Since it is sometimes useful to have a more precise measure of P than is afforded by the simple W. K. B. calculation, particularly in the neighborhood of the barrier, we have calculated and graphed $P(E)^{\frac{1}{2}}$ for protons on light nuclei using tables of the Coulomb wave functions of Yost, Wheeler, and Breit[1,2] and their extension by Wicher.[3] (See Figs. 1–7.) In their notation where F_L is the regular function with asymptotic form

$$F_L \rightarrow \sin[\rho - (L\pi/2) - \eta \ln 2\rho + \sigma_L],$$

and G_L the irregular function

$$G_L \rightarrow \cos[\rho - (L\pi/2) - \eta \ln 2\rho + \sigma_L],$$

we have defined P_L as $1/F_L^2(R)+G_L^2(R)$ in accord with recent investigations of Weisskopf[4] and Wigner.[5]

R is the nuclear radius and was taken to be

$$R = \frac{1}{2}\frac{e^2}{mc^2}(A_1^{\frac{1}{3}}+A_2^{\frac{1}{3}}),$$

where A_1 and A_2 are the atomic numbers of target and bombarding (proton) nuclei. In this way the curves for $L=0$, 1, 2 were drawn up (with occasionally some extrapolation of the existing tables). $L=3$, 4 were estimated at low energies from the first term of a Bessel function expansion.[1]

$P(E)^{\frac{1}{2}}$ is labeled Γ on the curves and is plotted on a logarithmic scale and normalized by using E in Mev. So that at high energies where $P=1$, $\Gamma=(E)^{\frac{1}{2}}$. The abscissa is a $1/(E)^{\frac{1}{2}}$ scale and in addition for convenience in interpolation a curve of E *vs.* $1/(E)^{\frac{1}{2}}$ is included with an appropriate ordinate scale on the right. The curves all approach straight lines at low energy corresponding to the limiting form

$$\Gamma \sim \exp(-2\pi Z_1 Z_2 e^2/hv).$$

Curves are given for only one isotope of each element but may be used for others since the variation with R is only slight.

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[1] F. L. Yost, J. A. Wheeler, and G. Breit, Phys. Rev. **49**, 174 (1936).
[2] F. L. Yost, J. A. Wheeler, and G. Breit, J. Terr. Mag. **40**, 443 (1935).
[3] E. R. Wicher, J. Terr. Mag. **41**, 389 (1936).
[4] H. Feshback, D. C. Peaslee, and V. F. Weisskopf, Phys. Rev. **71**, 145 (1947).
[5] E. P. Wigner and L. Eisenbud, Phys. Rev. **72**, 29 (1947).

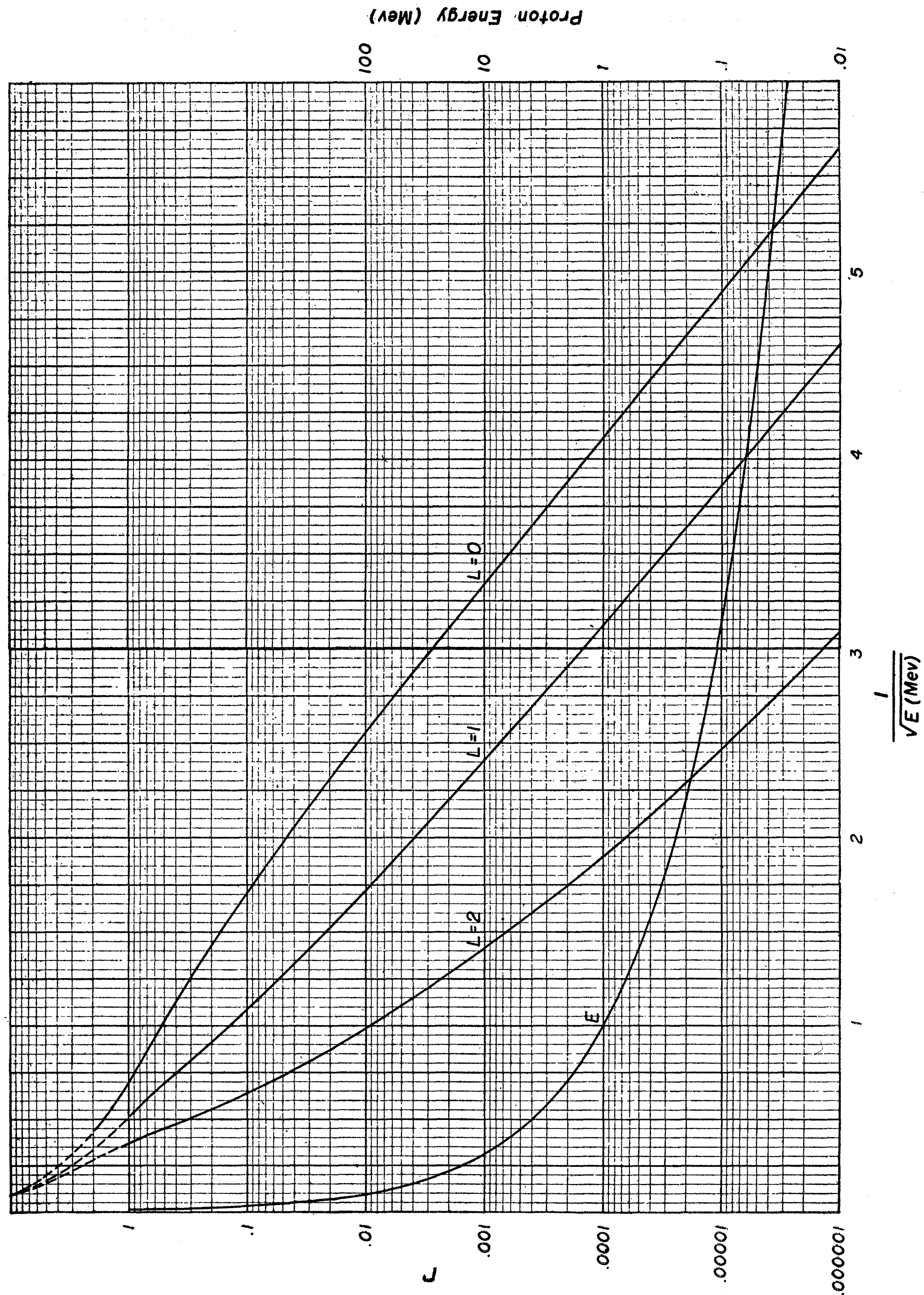

FIG. 1. Proton widths, Γ, for Li^7 normalized to 1 at 1 Mev without barrier.

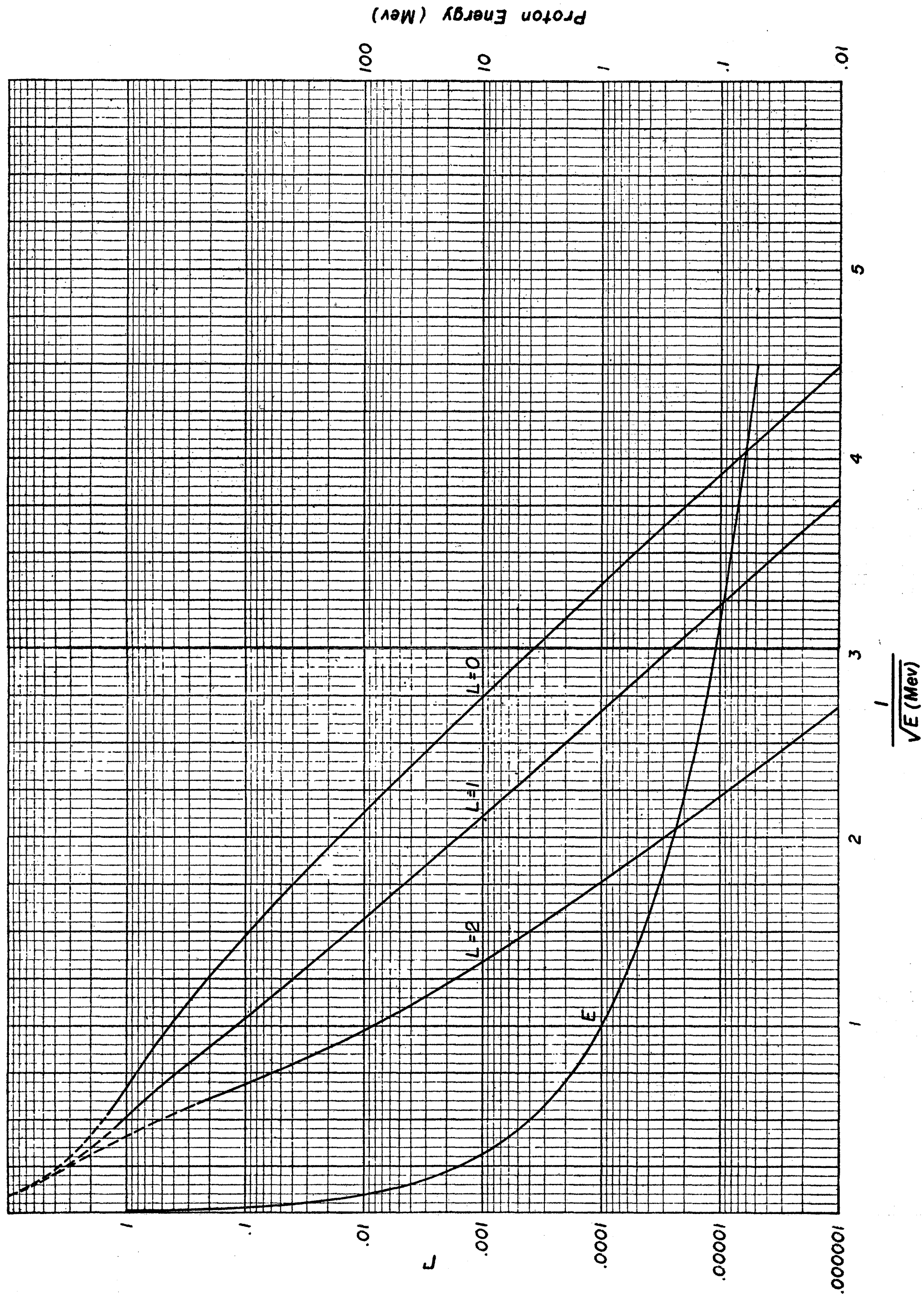

FIG. 2. Proton widths, Γ, for Be^9 normalized to 1 at 1 Mev without barrier.

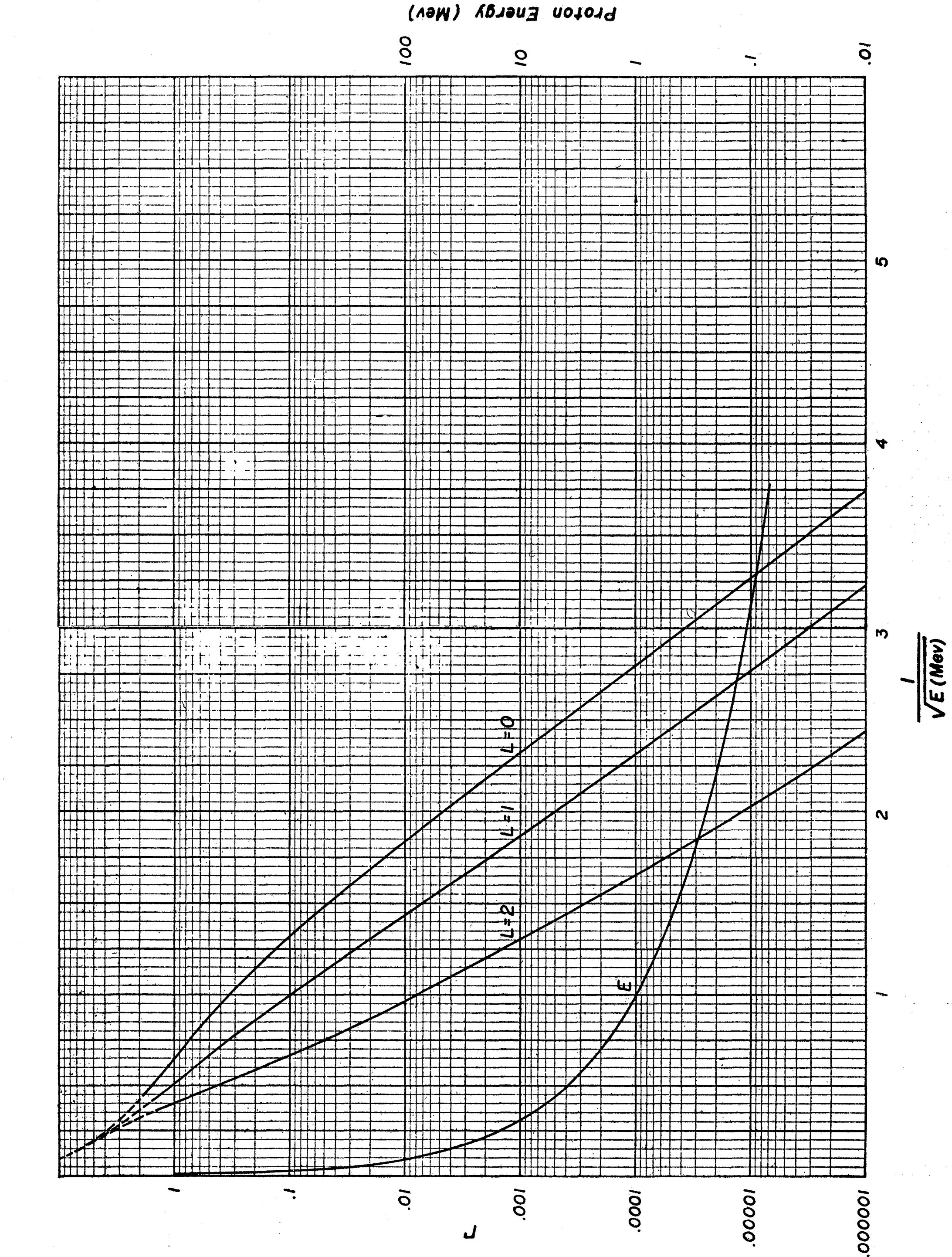

FIG. 3. Proton widths, Γ, for B^{11} normalized to 1 at 1 Mev without barrier.

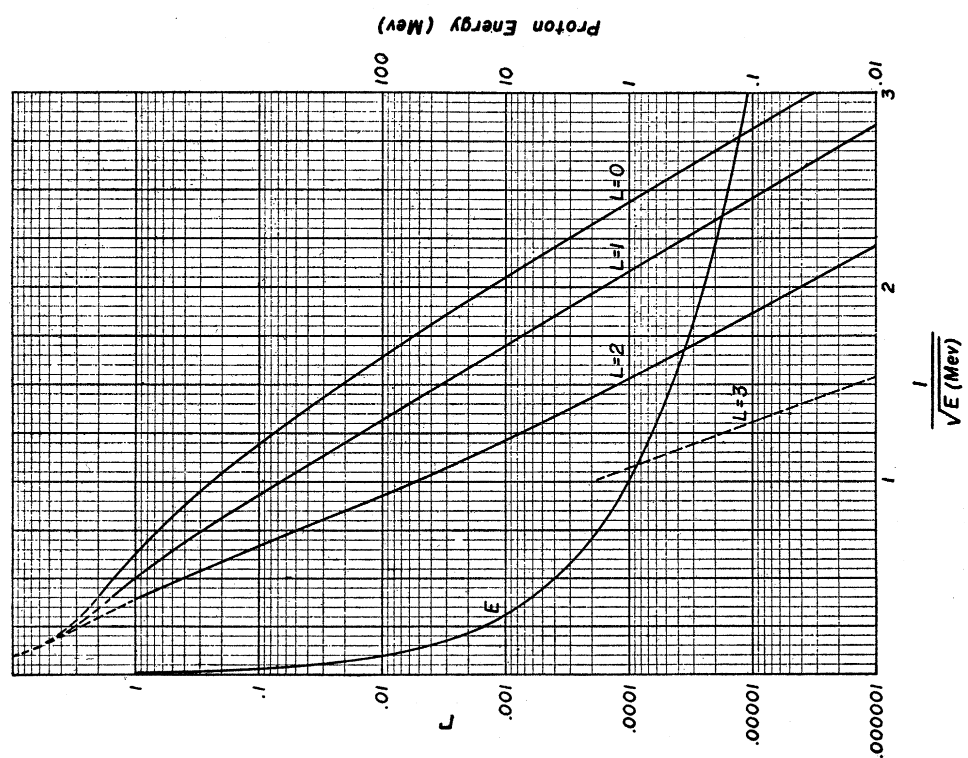

FIG. 4. Proton widths, Γ, for C^{12} normalized to 1 at 1 Mev without barrier.

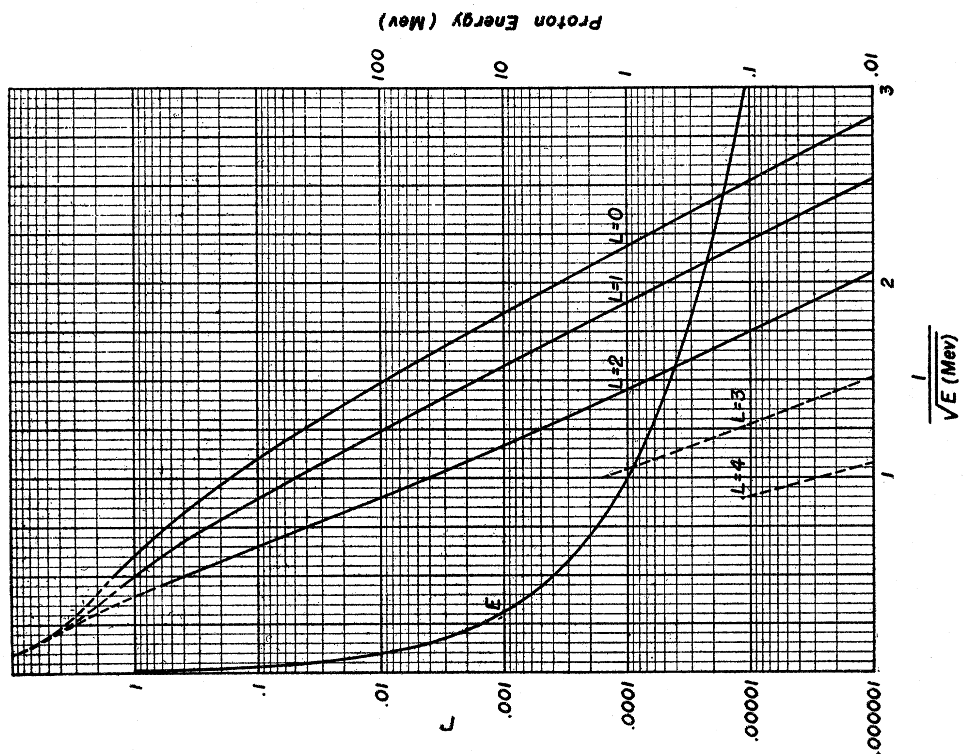

FIG. 5. Proton widths, Γ, for N^{14} normalized to 1 at 1 Mev without barrier.

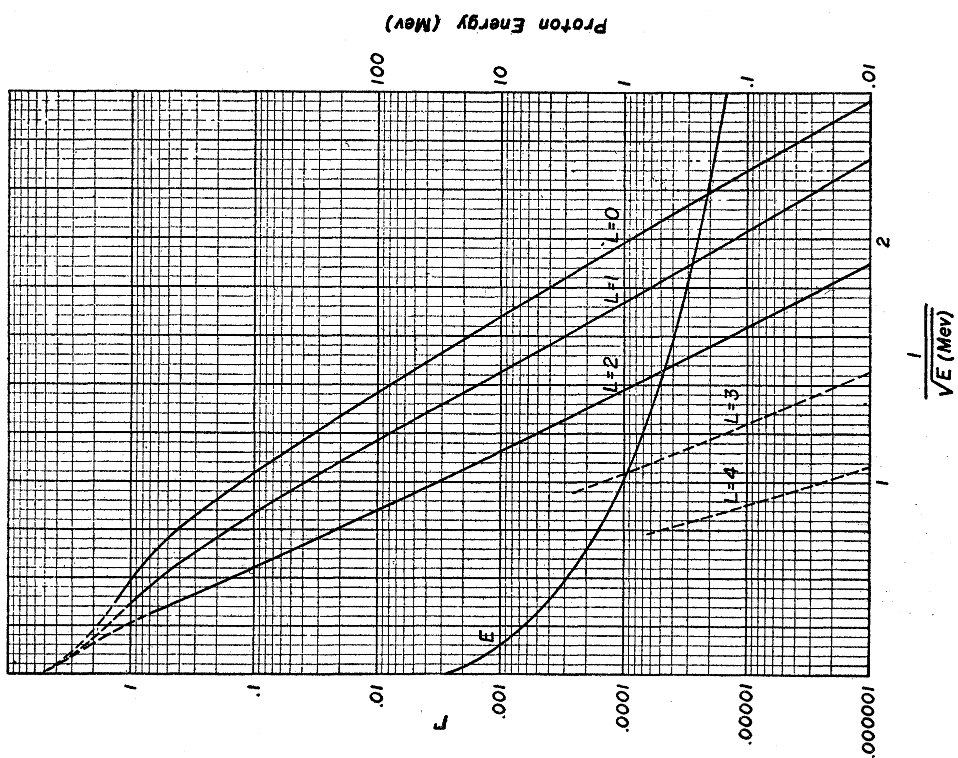

FIG. 6. Proton widths, Γ, for O^{16} normalized to 1 at 1 Mev without barrier.

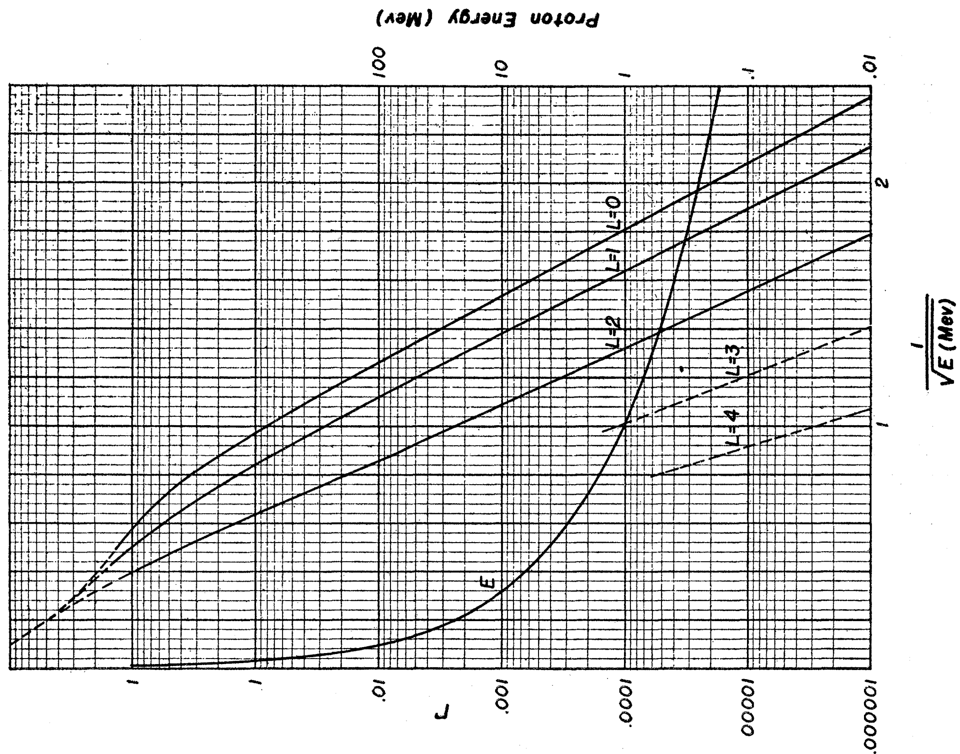

FIG. 7. Proton widths, Γ, for F^{19} normalized to 1 at 1 Mev without barrier.